Thermal and biological impacts of the coastal waves in the African upwelling areas at intraseasonal time scale

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Introduction

Although their strong social and economic consequences on surrounding countries, mechanisms for coastal upwellings along the tropical African coasts are not completely identified, in particular, competitions between local and remote (through coastal Kelvin waves) processes. Lagged correlations between sea level anomalies at the coast-equator and along the north and south coasts show that 25% of the variance in the upwelling areas is explained by the signal propagated along the coasts from the equator by the waves (Polo et al, 2007; near by poster).

In this work, we are interested in the thermal and biological impacts of the coastal waves in the upwelling areas along the African coasts (Figs.1a, b) . Using the mixed layer heat budget, coastal waves contribution to the horizontal advection of temperature can be evaluated and compared to the contribution of local forcing by wind stress which acts on vertical mixing, latent heat flux and local currents. The biological impact is also investigated.

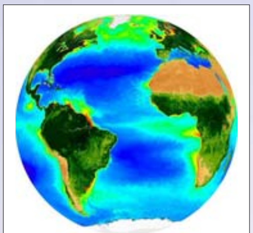

Fig.1a : Mean boreal summer SEAWIFS Chl (mg/m³)

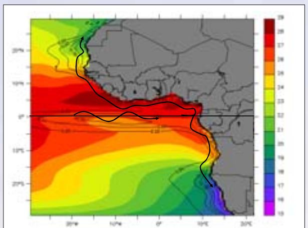

Fig.1b : Mean Reynolds SST (°C), ORCA05-PISCES Chl contours (mg/m³); equatorial and coastal Kelvin waves trajectories are schematized

1 Models and Data

To characterize the thermal and biological impacts of the coastal waves along the African coasts, we use Topex-Poseidon satellite data and two numerical runs to accede to the vertical distribution all along the waves trajectories and to calculate the mixed layer heat budget. The dynamical model (ORCA05) is forced with the ERA-40 atmospheric data sets and the turbulent heat fluxes are computed with bulk formulae. The second run also used ORCA05 for the oceanic dynamic and is coupled to the PISCES biological model (from Olivier Aumont). The first model runs from 1992 to 2000, the second one from 1948 to 2001; their horizontal resolution is 0.5° and there is 31 vertical levels (10 meters in the first 100m). The physical parameters are identical as in DRAKKAR simulations. The dynamic model has been validated by Polo et al (2007).

To visualize the wave propagation, we choose a 30-90 days time filter is applied to the SLA signal which is projected on the trajectory along the African coasts (Fig.2).

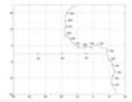

Fig.2 : Points defining the equatorial and coastal waves trajectories

2 Waves Periods along the African coasts

Both satellite and modeled SLA (Fig.3) shows equatorial and coastal waves along the African coasts until about 12°N and S with a 2 months periodicity, their amplitude varies between 1cm at the equator and 4cm at the coasts; their propagation phase speed is found to be in the range between the first and second Kelvin baroclinic modes (0.5 to 3m/s).

FFT analysis (Figs.4) reveals significant signal in both data and model at different intraseasonal timescales (around 60, 70 and 90 days). The energy quantity at these scales seems very well correlated to the local bathymetry (Fig.4.) but surprisingly not with the local stratification (not shown). The good agreement between wind stress FFT and SLA FFT (Fig.4) at these scale strongly suggest the propagativ nature of these signals, until 10-12° N and S; poleward, the intraseasonal variability of local forcing dominates.

Comparisons between FFT from model (Fig.4) and satellite data (Fig.4) exhibit some differences, in particular in the regions where the topography peaks. The big patches in the FFT from satellite data are certainly due to the aliasing between the tides and the satellite acquisition period (especially M2 -62 days- and N2 -58 days-).

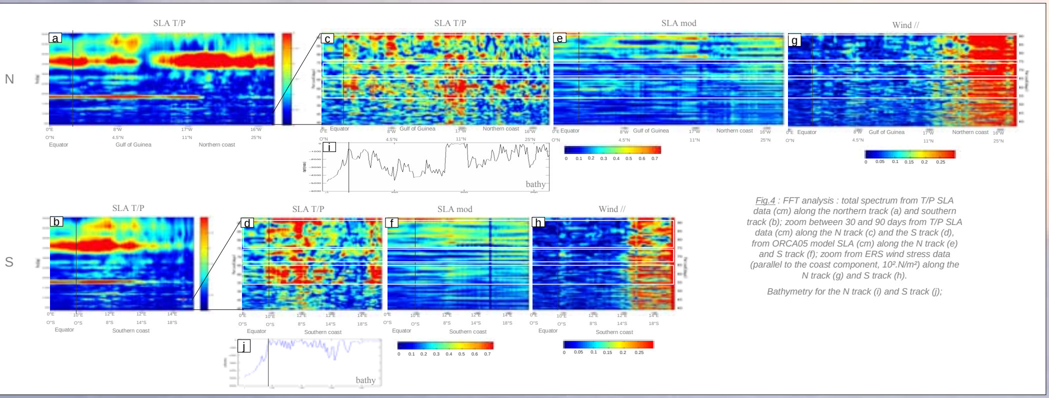

Fig.4 : FFT analysis : total spectrum from T/P SLA data (cm) along the northern track (a) and southern track (b); zoom between 30 and 90 days from T/P SLA data (cm) along the N track (c) and the S track (d), from ORCA05 model SLA (cm) along the N track (e) and S track (f); zoom from ERS wind stress data (parallel to the coast component, $10^2.N/m^2$) along the N track (g) and S track (h).

Bathymetry for the N track (i) and S track (j);

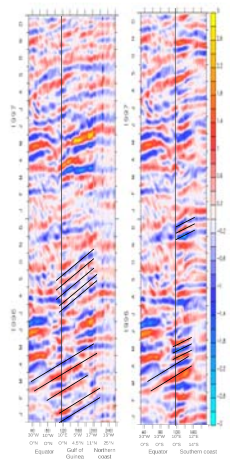

Fig.3 : Intraseasonal SLA along the equator, north (left) and south (right) coasts (cm)

3 Thermal Impact

The coastal waves can play a role on mixed layer heat budget in the horizontal advection and vertical diffusion terms, acting together in the coastal upwelling regions. Their influences on the temporal temperature evolution can only be significativ in the regions of strong vertical and horizontal temperature gradients. Therefore, these intraseasonal processes are extensively conditionned by the seasonal cycles of coastal upwelling .

The latent heat flux, responding to SST, often plays a preponderant role, attenuating or amplifying the horizontal advection and vertical diffusion, depending on wind stress direction and amplitude.

The constructiv combination of the two oceanic processes can lead to a 0.5°C/month variation (Fig.5f), as in 1996 spring in the Angola upwelling region when the atmosperic forcing does not oppose to oceanic processes activated by the coastal waves crossing (Figs.5). At the opposite (not shown), in December 2000, the latent heat flux is opposed to the horizontal advection and vertical diffusion and there is almost no influence on the SST, despite a very clear waves passage.

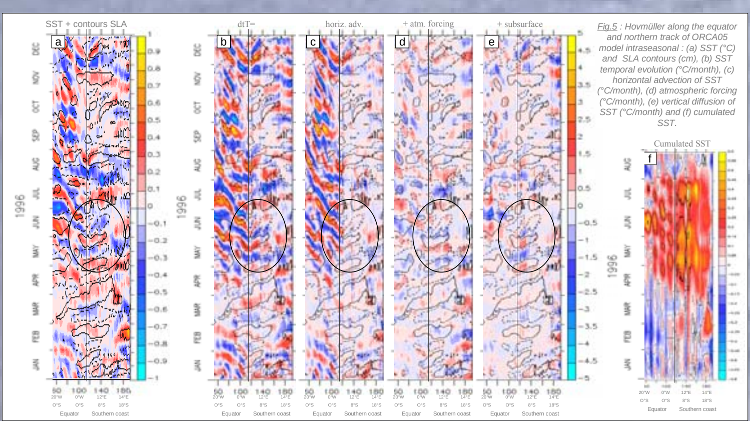

Fig.5 : Hovmüller along the equator and northern track of ORCA05 model intraseasonal : (a) SST (°C) and SLA contours (cm), (b) SST temporal evolution (°C/month), (c) horizontal advection of SST (°C/month), (d) atmospheric forcing (°C/month), (e) vertical diffusion of SST (°C/month) and (f) cumulated SST.

4 Biological Impact

Like for the thermal impact, the coastal waves seem to modify the intraseasonal variability of the biological activity, represented here as Chl signal, in the Angola upwelling region in 1996 spring (Fig.6b).

The background stratification (Fig.6a) play an important role on the signature of coastal wave on Chl intraseasonal variability (Fig.6b) : the coastal waves (~1cm=~10% variance) in april-may-june 1996 have a strong impact on Chl (~1mg/m³=~10% variance) when the thermocline (and then the nutricline, not shown) is shallow, despite in january-february-march, and this, with same order of wave amplitude, there is no signature on Chl signal because of the deep thermocline.

As expected, the equatorial and coastal waves signature in SLA are very well correlated with remote forcing by wind stress (Fig.6c) but it is the local one which forced the strong signal south of 15°S, acting on to the Chl through other processes (for examples horizontal advection) than wave propagation.

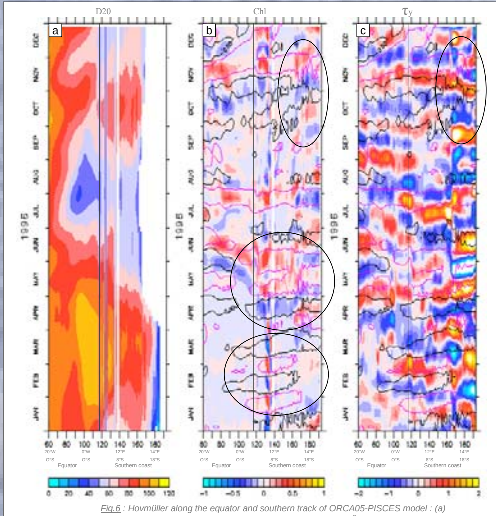

Fig.6 : Hovmüller along the equator and southern track of ORCA05-PISCES model : (a) low-frequency thermocline depth (m), (b) intraseasonal Chl (mg/m³) with SLA contours (cm) and (c) meridional wind stress ($10^2N/m^2$)

Conclusions and perspectives

The frequency analysis from SLA signal reveal several range of energetic period at intraseasonal time scale; we choose to extensively study the centered on 60 days one but it would be interesting to explore the lower periods (especially in the range 75-90 days, very energetic).

Modulated by local bathymetry and background stratification, the coastal waves can strongly impact the SST (until 0.5°C) and the Chl (until 0.5 mg/m³) in the region between the equator and the critical latitudes (~10-12°N and S) where local forcing by intraseasonal wind stress is weak. At the opposite, poleward to these latitudes, the local atmospheric forcing, governed by subtropical anticyclones, are dominant and hide a possible coastal wave signature on thermal, biological or dynamical signals.

To discriminate local and remote forcing, sensibility tests to wind stress will be lead with numerical regional configurations.

Coupled to the biological model PISCES, these new configurations will allow to explore the differents processes responsible of Chl temporal evolution.

References and Acknowledgments

- Polo, I., A. Lazar, B. Rodriguez-Fonseca, S. Arnault, 2008: Oceanic Kelvin Waves and Tropical Atlantic intraseasonal Variability. Part I: Kelvin wave characterization, in press in J. Geophy. Res. Ocean

- The coupled ORCA05-PISCES model has been performed by Olivier Aumont (Ifremer, Brest).
- The FFT analysis has been computed and filled by A. Arakelian and J. Barre (LOCEAN, Paris)